PB84-177864

Disinfection and the Control of Waterborne Giardiasis

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

1984

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-177864

EPA-600/D-84-101
April 1984

DISINFECTION AND THE CONTROL OF WATERBORNE GIARDIASIS

by

J. C. Hoff and E. W. Rice
Municipal Environmental Research Laboratory
Cincinnati, OH 45268

and

F. W. Schaefer, III
Health Effects Research Laboratory
Cincinnati, OH 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/D-84-101	2.
3. RECIPIENT'S ACCESSION NO. PB84 177864	
4. TITLE AND SUBTITLE Disinfection and the Control of Waterborne Giardiasis	5. REPORT DATE 1984
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J. C. Hoff, E. W. Rice, and F. W. Schaefer III	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS J. C. Hoff, DWRD, MERL E. W. Rice, DWRD, MERL F. W. Schaefer III, T&MD, HERL U.S. EPA, 26 W St Clair St. Cincinnati OH 45268	10. PROGRAM ELEMENT NO. BNC1A 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory U.S. Environmental Protection Agency 26 W St Clair St Cincinnati, OH 45268	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/600/14
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

In the early 1970's, when giardiasis began to be recognized as an important waterborne disease, our understanding of the effects of disinfectants on the cysts of the etiologic agent, Giardia lamblia, was extremely limited. The results of more recent studies, using improved methods for determining cyst viability indicate that Giardia cysts are more resistant to inactivation by drinking water disinfectants than other waterborne bacterial and viral pathogens but are not as highly resistant as indicated by earlier studies. The data now available indicate that rigorously controlled disinfection practices are essential in preventing waterborne transmission of giardiasis.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release to public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 9
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

DISINFECTION AND THE CONTROL OF WATERBORNE GIARDIASIS

J. C. Hoff,[1] E. W. Rice,[1] and F. W. Schaefer III[2]

ABSTRACT

In the early 1970's, when giardiasis began to be recognized as an important waterborne disease, our understanding of the effects of disinfectants on the cysts of the etiologic agent, Giardia lamblia, was extremely limited. The results of more recent studies, using improved methods for determining cyst viability indicate that Giardia cysts are more resistant to inactivation by drinking water disinfectants than other waterborne bacterial and viral pathogens but are not as highly resistant as indicated by earlier studies. The data now available indicate that rigorously controlled disinfection practices are essential in preventing waterborne transmission of giardiasis.

INTRODUCTION

Although few waterborne outbreaks of giardiasis were reported in the U.S. prior to 1970, the number of documented outbreaks has increased greatly since then (3). Our lack of knowledge of the effectiveness of disinfection for control of waterborne giardiasis (5) stimulated research in this area. Following development of biological methods for determining cyst viability (2,12) and initiation of the use of a related species, (G. muris), infective for mice as a model (11,16) our knowledge of the effects of disinfectants on this pathogen is being rapidly extended. This paper describes the results of these recent studies and their implications for water treatment.

DISINFECTION STUDIES

All of the results cited were obtained in laboratory scale investigations. Unless otherwise stated the studies were conducted under carefully controlled conditions with stable disinfectant concentrations. Although some of the studies were conducted at higher temperatures, much of the disinfection research has been conducted

---

[1]Microbiologist, Drinking Water Research Division, Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268

[2]Microbiologist, Toxicology and Microbiology Division, Health Effects Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268

at low water temperatures (≤ 5°C) because inactivation rates are slower at low temperatures and thus represent "worst case" conditions for disinfectant efficiency. Low water temperatures would be typical for several months each year in many locations where giardiasis outbreaks have occurred. When possible, results are expressed as the disinfectant concentration and exposure time necessary for inactivation of 99 percent of the cysts or other microbial populations compared. The results also are expressed in terms of CT which is defined as the disinfectant concentration (C) in mg/L, times the time (T) in minutes required to inactivate a given percentage of the population (e.g. 99 percent) under defined pH and temperature conditions.

Chlorine

Data from several investigations showing the comparative resistance of *Giardia* cysts and several other types of microorganisms to free chlorine in the form of hypochlorous acid are shown in Table 1. The CT data indicate that the resistance of *Giardia*

Table 1 Inactivation of Various Microorganisms by Free Chlorine at 5°C, pH 6.0.

Microorganism	Chlorine Conc. (mg/L)	Time[a] (min)	CT	Reference
E. coli.	0.1	0.4	0.04	14
Poliovirus 1	1.0	1.7	1.7	14
E. histolytica[b] cysts	5.0	18	90	17
G. lamblia[c] cysts	1.0	50	50	6
	2.0	40	80	6
	4	20	80	6
	8	9	72	6
G. lamblia[c] cysts	2.5	30	75	11
G. lamblia[d] cysts	2.5	100	250[b]	11
G. muris cysts	2.5	100	250[b]	11

[a] for 99% inactivation; [b] extrapolated data; [c] cysts from symptomatic carriers; [d] cysts from asymptomatic carrier

cysts is on the order of 2 orders of magnitude higher than that of the enteroviruses, represented by poliovirus 1 and more than 3 orders of magnitude higher than the enteric bacteria represented by *Escheri-*

chia coli. CT results for G. lamblia based on cysts from the same source using different chlorine concentrations and exposure times are very similar. The results also indicate that G. lamblia from different sources may vary in resistance and that G. muris cysts are similar in resistance to G. lamblia cysts.

Additional data showing the effects of temperature pH and chlorine species on cyst inactivation are shown in Table 2. The general

Table 2. Effects of Temperature, pH and Chlorine Species on Giardia Cyst Inactivation

Form of Chlorine	Temp (°C)	pH	Chlorine conc. (mg/L)	99% Inactivation Time (min.)	CT	Reference
Free	25	6	1.5	< 10	< 15[a]	6
		7	1.5	< 10	< 15	6
		8	1.5	< 10	< 15	6
Free	15	6	2.5	7	18[a]	6
		7	2.5	20	50	6
		8	2.5	25	63	6
Free	5	7.8	5	30	150[b,c]	4
		7.8	2	180	360	4
Free	1	7.8	5	60	300[b,c]	4
		7.8	2	240	480	4
Chloramine	18	6.5	2.3	70	161[b,c]	d
		7.5	2.1	80	168	
Chloramine	10	7.0	1.8	230	414[b]	d
Chloramine	3	6.5	2.6	180	468[b]	d
		7.5	2.4	220	528	

[a] Giardia lamblia cysts; [b] Giardia muris cysts; [c] 3 day old cysts; [d] Bingham, A. K. and Meyer, E. A. Unpublished data.

decrease in inactivation rates at lower temperatures is evident. The decrease in free chlorine efficiency with increasing pH is due to the shift from the more effective hypochlorous acid form to the less effective hypochlorite form. The results also point up the lower disinfection efficiency of chloramine. The differences between free and combined chlorine efficiency appear to be greater at higher temperatures. There is some evidence that cyst age may influence chlorine resistance with older cysts being more resistant (4).

Ozone

Comparative inactivation of Giardia muris cysts and other types of microorganism by ozone is shown in Table 3. The overall

Table 3. Inactivation of Various Microorganisms by Ozone

Micro-organism	pH	Temp. °C	C mg/L	T min	CT	Reference
E. coli	7.2	1	0.07	0.083	0.006	8
	7.2	1	0.065	0.33	0.022	8
Poliovirus 1	7.2	5	0.15	1.47	0.22	13
G. muris	7.0	5	0.15	12.9	1.94	18
			0.7	2.8	1.96	

resistance pattern is similar to that for chlorine with cyst resistance being approximately 1 order of magnitude higher than poliovirus 1 and 2 to 3 orders of magnitude higher than E. coli. The much lower CT number also points up the much higher efficiency of ozone compared with chlorine.

ULTRAVIOLET RADIATION

The use of ultraviolet radiation for low maintenance, cost effective disinfection in small water supply systems is under active consideration. The results of laboratory studies on its effectiveness against G. lamblia cysts (10) indicate that at the maximum dose used (63,000 uW-sec/cm^2), less than 80% of the cysts were inactivated while a dose of 3,000 uW-sec/cm^2 inactivated 99.9% of an exposed E. coli population. This is very significant when one considers that the maximum designed dose range of many commercially available ultraviolet treatment units is 25,000 to 35,000 uW-sec/cm^2. Other studies in progress confirm the high resistance of Giardia cysts to ultraviolet radiation (Carlson, D. A. Unpublished data).

SMALL QUANTITY WATER DISINFECTION

The effectiveness of several emergency water disinfection methods also has been studied (7). At 3°C several of the methods (bleach, Globuline, 2% tincture of iodine) failed to effectively inactivate G. lamblia cysts in clear water. The reason for the failures in the case of bleach, Globuline, and 2% tincture of iodine was that the doses recommended for clear water were only half those recommended for cloudy water under the rationale that cloudy waters would exert disinfectant demand while clear waters would not. These reduced levels of disinfectant did not reduce viability below the limit of detectability (99.8%) at 3°C. At 20° C, all of the methods reduced cyst viability to levels below the limits of detectability. Marchin et al. (9) demonstrated the effectiveness of demand type disinfectants based on iodine bound

to quaternary ammonium anion exchange resins. Bingham, et al. (1) demonstrated that cysts exposed to boiling water were killed immediately. Schaefer et al. (15) reported a thermal death point of 54°C for G. muris cysts.

CONCLUSIONS

The results of recent studies indicate that contrary to our general impressions 10 years ago, Giardia cysts can be inactivated by drinking water disinfectants. They are among the most resistant pathogens known, however, and the disinfection step must be conducted rigorously under well controlled conditions. This is especially important during periods when water temperatures are low. The importance of employing treatment processes to remove substantial numbers of cysts prior to disinfection also is important so that the reliance on disinfection is decreased.

REFERENCES

1. Bingham, A. K., Jarroll, E. L., and Meyer, E. A. "Giardia sp.: Physical Factors of Excystation in vitro and Excystation vs. Eosin Exclusion as Determinants of Viability," Exp. Parasitol. 47, 284-291 (1979).

2. Bingham, A. K. and Meyer, E. A. "Giardia Excystation Can Be Induced in vitro in Acidic Solutions," Nature (London) 277, 301-302 (1979).

3. Craun, G. F., "Waterborne Giardiasis in the United States: A Review," Am. J. Public Health 69, 817-819 (1979).

4. DeWalle, F. B. and Jansson, C. R. E. "Inactivation of Giardia by Chlorine and UV," Proc. Seminar on Giardiasis and Public Water Supplies. British Columbia Water and Waste Assn. Richmond, B. C. Nov. 22, 1983.

5. Hoff, J. C., "Disinfection Resistance of Giardia Cysts: Origins of Current Concepts and Research in Progress," In Proc. Symp. on Waterborne Transmission of Giardiasis, EPA-600/9-79-001, Cincinnati, Oh., Sep. 18-20, 1978.

6. Jarroll, E. L., Bingham, A. K., and Meyer, E. A. "Effect of Chlorine in Giardia lamblia Cyst Viability," Appl. Env. Microbiol. 41, 483-487 (1981).

7. Jarroll, E. L., Bingham, A. K., and Meyer, E. A. "Giardia Cyst Destruction: Effectiveness of Six Small Quantity Water Disinfection Methods," Am. J. Trop. Med. Hyg. 29, 8-11 (1980).

8. Katzenelson, E., Kletter, B., and Shuval, H. I. "Inactivation Kinetics of Viruses and Bacteria in Water by Use of Ozone." J. Am. Water Works Assoc. 66, 725-729. (1974).

9. Marchin, G. L., Fina, L. R., Lambert, J. L., and Fina, G. T. "Effect of Resin Disinfectants-I_3 and -I_5 on Giardia muris and Giardia lamblia." Appl. Env. Microbiol. 46, 965-969. (1983).

10. Rice, E. W., and Hoff, J. C. "Inactivation of Giardia lamblia Cysts by Ultraviolet Irradiation." Appl. Env. Microbiol. 42, 546-547 (1981).

11. Rice, E. W., Hoff, J. C., and Schaefer III, F. W. "Inactivation of Giardia Cysts by Chlorine." Appl. Env. Microbiol. 43, 250-251 (1982).

12. Rice, E. W. and Schaefer III, F. W. "Improved in vitro Excystation Procedure for Giardia lamblia Cysts." J. Clin. Microbiol. 14, 709-710 (1981).

13. Roy, D., Engelbrecht, R. S., and Chian, E. S .K., "Comparative Inactivation of Six Enteroviruses by Ozone." J. Am. Water Works Assoc. 74, 660-664 (1982).

14. Scarpino, P. V., Berg, G., Chang, S. L., Dahling, D. and Lucas, M. "A Comparative Study of the Inactivation of Viruses in Water by Chlorine," Water Res. 6, 959-965 (1972).

15. Schaefer III, F. W., Rice, E. W., and Hoff, J. C. "Factors Promoting In Vitro Excystation of Giardia muris Cysts." Trans. Roy. Soc. Trop. Med. Hyg. In press.

16. Schaefer III, F. W., Rice, E. W., and Hoff, J. C. "In vitro Excystation of Giardia muris Cysts." In Proc. 55th Ann. Meeting of the American Society of Parasitologists, (Abst. #90), Berkeley, Calif. Aug. 48, 1980.

17. Snow, W. B. "Recommended Chlorine Residuals for Military Water Supplies." J. Am. Water Works Assoc. 48, 1510-1514 (1956).

18. Wickramanayake, G. B., Rubin, A. J., and Sproul, O. J. "Inactivation of Naegleria and Giardia Cysts in Water by Ozonation." J. Water Pollution Control Fed. In press (1984).